# DESIGN OF A TRANSIENT SWEATING HOT PLATE

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## INTRODUCTION

In studying the combined heat and water transport through clothing, it has been found necessary to treat the phenomenon as the dynamic one that it is [1,2]. During the time a garment is wom by an active person, the heat flow through it is rarely constant. Heat flow mechanisms such as water vapour diffusion and wind can be highly unsteady due to the nature of their sources. Their interaction with the other major heat transfer mechanisms of air conduction and thermal radiation make the overall heat transfer highly unsteady.

An apparatus used to study heat and water transport through clothing is the Sweating Hot Plate or Guarded Hot Plate. A steady state version is used to measure heat and vapour resistances under steady state conditions. However, to truly characterize the dynamic situation, a Sweating Hot Piate capable of simulating the transient behaviour of water vapour and measuring the resulting dynamic heat **loss** is required. Such an instrument has been developed and used by Dr. Brian Farnworth and Patricia Dolhan at Defence Research Establishment (DREO), Ottawa, Canada [1,2]. This paper describes the design of a new transient Sweating Hot Plate which is a state of the art version of the DREO prototype.

## THE ORIGINAL DESIGN:

The DREO version consisted of what can be called a thermal sandwich assembly mounted in a cut out in an insulated box containing the sweat mechanism. The whole unit could then be placed in a small environmental chamber for studies at other than room conditions.

The thermal sandwich consisted of a paper (and later cotton) top covering over a 3 mm thick aluminum plate. This plate was divided into an inner circular test section of area 0.01 $m^2$ and an annular guard ring of the same area. Each of these sections had four *(4)* evenly distributed water feed lines to simulate sweat. Under the aluminum plate was a 50 mm thick piece of insulation and under that a 3 mm thick aluminum base plate. Thermocouples imbedded in the plates and heaters attached to them allowed the test plate, guard ring and base plate to be controlled to the same temperature so that all heat flow from the test plate was vertically upwards through the specimen that was placed on top of it.

The sweat mechanism consisted of two (2) syringe pumps and eight (8) solenoid valves. The syringe pumps could be started and stopped manually from the computer keyboard and the solenoid valves were sequenced by the computer to ensure uniform water delivery to the eight (8) water feed lines.

The box served as a mounting for the thermal sandwich and as a thermal protective environment for the sweat mechanism when the unit was placed in an environmental chamber.

## THE NEW DESIGN:

A new Sweating Hot Piate has been designed and built by The CORD Group Limited which brings the design up to the state-of-the-art and adds features that make it more versatile.

THE NEW DESIGN (Cont.)

The thermal sandwich of the CORD Hot Plate is of a lower mass design in order to improve the transient response. This has been done by thinning the test and guard plates to 1.5 mm and eliminating the base plate. The insulation has also been thinned to 6.4 mm. The transverse temperature uniformity at all levels within the thermal sandwich has been improved by changing the metal to copper (because of its higher thermal diffusivity) and by the use of etched foil heaters. The accuracy of temperature measurement and heat flux blocking by the guard ring and base insulation has been maintained or improved by the use of 2000 OHM thin film distributed RTDs for temperature measurement. The result is that the total thickness of the CORD thermal sandwich is only 9.5 mm as compared to 56 mm in the old design.

The sweat mechanism of the new Hot Piate has also been improved. Instead of eight (8) feed lines to the plate, there are twenty-four **(24)** and each is fed by a separate piston eliminating the need for in-line solenoid valves. The larger number of feed lines improves the uniformity of sweat distribution over the old design. The new Hot Piate also has a Lycra covering with a special wicking finish which improves its response time during the onset and decay of transient sweat profiles.

The individual sweat pistons are driven by a single micro step drive stepping motor through a lead screw. This makes possible the accurate and automatic control of virtually any sweat profile by the software. The sweat reservoir holds enough water for twenty-four **(24)** hours and can be refilled on the run providing the ability to run tests indefinitely.

The CORD sweat mechanism also has applications elsewhere; for instance, it could be incorporated into a sweating manikin.

With the CORD Sweating Hot Plate, the specimen can be subjected to differing environmental conditions in several ways. The whole unit itself is designed to be placed in a small (24" X 24" X 24") environmental chamber for ambient temperature simulation. Also, a small environmental housing has been designed to attach directly to the Hot Plate Itself. This housing allows for temperature, medium and pressure control over the thermal sandwich. For instance, one can do tests on a specimen immersed in water and include the effects of pressure on the specimen thickness.

A further feature of the design is that the thermal sandwich can be rotated through 180 degrees **so** that specimens can **be** tested in different orientations including completely upside down. This allows for studies including the effects of the thermal boundary layer as a function of orientation.

The Hot Plate can be run from a P.C. computer using a data acquisition and control system having proportional power output capability or it can be operated directly from a P.C. using its own data acquisition and control board, interface unit and software.

The CORD transient Sweating Hot Piate is a very versatile device that can be of use to researchers who do transient or steady state studies. **It** is available for purchase or lease from The CORD Group Limited. Testing services can also be provided on a contract basis.

REFERENCES:


**1.** Farnworth, B. and Dolhan, P.A., "Heat and Water Transport Through Cotton and Polypropylene Underwear", Textile Research Journal, Vol. **55, *No.*** 10, October, *1985*

**2.** Farnworth, **B.**, "A Numerical Model of the Combined Diffusion of Heat and Water Vapor Through Clothing", Textile Research Journal, Vol. 56, No. **11,** November, 1986